THE MINERALOGICAL AND PETROGRAPHIC CHARACTERISTIC OF THE JURASSIC AQUIFER IN THE MOGILNO-ŁÓDŹ TROUGH

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Introduction

Poland has one of the richest low-enthalpy geothermal resources in Europe, suitable conditions of the occurrence of geothermal water aquifers and their exploitation in many regions. Geothermal energy in Poland has been used for heating purposes in 1992 since the first geothermal plant has started to operate in the Podhale region. The space heating is a key sector for the Polish geothermal and there is a growing interest in recreation and balneotherapy, what has been expressed by seven new centers open in recent years (Bujakowski & Tomaszewska 2014; Górecki et al. 2015; Kępińska 2018; Sowiżdżał 2018). The main geothermal water resources are associated with the Mesozoic sedimentary formations of the Polish Lowlands where thermal waters are accumulated in the sands of the Lower Cretaceous and the Lower Jurassic formations and in the Podhale region in the Carpathians.

The Lower Jurassic aquifers are characterized by the largest dispositional resources among geothermal aquifers in the Polish Lowlands. The Lower Jurassic geothermal reservoir consists of a fine and mixed grain-size sands and sandstones layers from 10 to 650 m thick; depending on the depth. The water within the reservoir exhibits a mineralization ranging from 2 to over 100 g L^{-1} and its temperature ranges from 313 to 353 K. The reservoir area is 158,600 km^2, i.e. around 51% of the area of Poland (Górecki ed. 2006; Sowiżdżał 2018).

The basic condition for the accumulation of groundwater is a existence of reservoir rocks with favorable parameters. Waters that filling the space rocks should be characterized by appreciate parameters, such as temperature, efficiency and mineralization, indicating the possibility of their use for different purpose: heating, balneology, recreation etc. The type of the rocks forming the Mesozoic formations of the Mogilno-Łódź Trough contribute to occur the fissured and pore-fractured water aquifers composed mainly of sandstones, mudstones and carbonate rocks.

Samples and methods

Twelve samples of the Lower Jurassic rock formations were collected from the Mogilno-Łódź Trough from borehole cores: Banachów IG-1, Koło IG-3, Koło IG-4, Poddębice PIG-2 and Damasławek 22. A small number of samples resulted from the limitations of the size of cores in the archives. Also, collected for detailed mineralogical, petrographic study cores had to meet the size requirements for microscopic examination. Basic parameters such as porosity, permeability, specific surface area have been identified. Thin sections were used for microscopic and pore analysis. Laboratory studies included macroscopic and microscopic observations. Rock samples were subject to microscopic optical examination, accompanied by scanning electron microscopy (SEM) and X-ray diffraction inspections (XRD). Porosity analysis of the rocks examined was carried out by microscopic observations of the thin sections and through petrophysical inspections of rocks by means of measurements of capillary action.

Results

Rocks collected from all wells can be classified petrographically as sandstones represent mainly by quartz arenites. A skeleton size distribution of these sandstones are characterized by a well sorted clastic material except the sample from the borehole Koło IG- 4 (2732.5 m b.g.l.), where a level of sorting was low. The studied sandstones are characterized by a monotonous mineral composition. In all samples, the framework is dominated by quartz grains from 95 % to 99 %. All analyzed samples contain quartz lithoclasts (up to 1%). Size of quartz grains are varied, from 0.05 to 0.6 mm, mainly characterized by ellipsoidal shape, less isometric or spindle. Most of quartz grains are characterized by the presence of regenerative edging, as well as the dissolution traces pressure. Feldspars, represented by plagioclase and pertyt up to 0.2 mm, occur sporadically in samples, maximally to 1% of the rock skeleton in the sample from Damasławek 22 borehole. Their sizes are up to 0.2 mm and mostly are completely changed as a result of seretyzations or replaced by iron-clayey substance similar to the matrix one. Micas, represented by 0.2 to 0.3 mm long muscovite and chlorites sheets, are commonly in framework of all Lower Jurassic sandstones, as well as heavy minerals: zircon, tourmaline and apatite (their sizes rarely exceed 0.1 mm).

The cement in the studies arenits is consist mainly from regenerative quartz (80%) and clay minerals - kaolinit (10-15%). Porous carbonate cement and iron-clayed matrix occur in small amounts. Anhydrite cement was also observed in sample from the Damasławek 22: 3391.3 m b.g.l.

The results of automatic porosity analysis made on thin sections of the profile of Lower Jurassic indicate a very close degree of porosity of all sandstones. Porosity varies from 7 to 14%. The lowest porosity showed a sample from Poddębice PIG-2 (3364.5 m b.g.l.) in other hand in this profile also occur the most porous sandstone sample (3623.0 m b.g.l.). In general, the porosity of the studied rock was 11-12%. From the petrophysic examination the total porosity of the studied samples ranges from 7.88 to 14.83%, effective porosity from 6.75 to 13.38%. The specific surface area varies from 0.01 to 1.82 m^2/g. The size of this surface informs about the development of the pore space in the directions of micropores. The larger the surface are, the more micropores in the rock. The size of the surface area equal to zero indicates the lack of pore space, i.e. virtually no porosity.

The permeability perpendicular to the core axis is from 0.151 to 129.023 mD. The permeability parallel to the core axis is from 0.141 - 95.58 mD. In the sample from the Damasławek-22 well (3391.3 m b.g.l.) the permeability parallel to the core is 5 times greater than the permeability perpendicular to the core axis. Anomalously low permeability in relation to the pore space parameters is shown in the Koło IG-4 sample (2732.4 m b.g.l.). Lowering the permeability in relation to the pore space parameters is related to the partial cementation of the rock. Cements in the rock are nested and the sample has very low permeability despite very good parameters of the pore space.

Conclusions

The success of deep geothermal projects depends on the properties of the geothermal aquifers. The aim of the presented analysis was to broaden the knowledge about the Lower Jurassic geothermal aquifer in the Mogilno-Łódź Trough. The results of the petrographic and mineralogical studies of core samples confirmed the presence of rock with favorable parameters for the accumulation of thermal waters. This promotes the use of high efficiency, which has a positive effect on the economic justification for the construction of geothermal heating plants. Understanding the occurring processes and mechanisms are needed also to develop aquifer management.

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